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The ending of the ceremony is similar to that described in the Yuma ceremonies.

The cardinal points are symbolized among the Apaches thus:

East—Black.

South—White

West—Yellow.

North—Blue.

The sun in the east is called the "black sun." A wind gust or tornado is also called "black."

NINETY-SIXTH REGULAR MEETING, May 5, 1885.

Vice-President Col. GARRICK MALLERY, U. S. A., in the Chair.

The Secretary of the Council announced the election of Hon. W. B. Snell, Justice of the Police Court, and Mr. L. J. Hatch, of the Bureau of Engraving and Printing, as active members of the Society, and informed the Society that the Council had determined to print Vol. III of the Transactions of the Society.

Col. F. A. SEELY read a paper entitled "THE GENESIS OF INVENTIONS."

During the past few years unusual attention has been directed to the study of human inventions. The close relations between the amelioration of man's condition and the improvement of his mechanic arts have led to the consideration of the subject as one in which social science is concerned. It has been observed that institutions of every character—languages, laws, customs, philosophies, and beliefs—have been largely, if not wholly, the product of invention of somewhat the same character as that which has produced tools and machines. The term invention has acquired a broader scope, and includes every subject on which human thought and ingenuity and fancy may exercise themselves. Its study is therefore of no little consequence. It is no longer limited to the field of mere mechanics and physics, but embraces all that concerns whatever has been devised by men to satisfy the material and moral needs, either of the individual or of the mass in their various social relations. I propose to inquire what are the processes by which inventions are produced; what influences lead to them; what laws,

if any, they follow; and what results, immediate and ultimate, flow from them. I conceive that these inquiries are best pursued in connection with mechanical inventions. A parallel inquiry might be pursued in respect to inventions in the broader sense. In fact the study of savage society is, to a certain extent, such an inquiry.

Before proceeding to the consideration of the subject, it is important to call attention to the various meanings and shades of meaning of the word *invention*, which we have such constant occasion to employ. A late writer on Patent Law* refers to this in his opening chapter as a source of much confusion, since, as he remarks, it is not uncommon to find the word used in different senses in the same paragraph, even in the same sentence. He distinguishes four meanings of the word :

- (1) The mental act of inventing.
- (2) The thing invented.
- (3) The fact that an invention has been made.
- (4) The faculty or quality of invention.

It is scarcely necessary to illustrate these significations, since on a little reflection they become apparent. We may say of the sewing machine, *it was the invention of Howe*, referring to the mental process which produced it; we may say *it is a great or useful invention*, meaning the machine itself; we may say *the invention of it revolutionized the manufacture of clothing*, in which we mean the fact that it was made; and we may say of any particular form presented to us, *there is no invention in it over some earlier form*, in which we refer to the quality of invention as distinguished alike from the mental act, the concrete product, and the historical fact. In view of all these uses of the word and not to overload it further, I shall venture to suggest a new one to designate the study of invention. This study has not yet perhaps developed itself as a true science, though it appears to possess all the elements of a science. As a study of growing interest it is worthy of a name of its own, and, with all deference, I submit to the Society, as an appropriate name worthy of adoption the word *Eurematics*.† This should include the study not of arts, machines, laws or insti-

* Merwin. Patentability of Inventions. Boston. 1883.

† *Εὑρημα*, An invention. If the Greeks had been in the habit of philosophizing about inventions, they would have had an adjective, *εὐρηματικός*, and the word would have found its place in English long ago, as has *eureka*.

tutions in themselves, but of them all in respect to their methods of growth and the means by which they have been developed and are still developing. This is a study which many are pursuing with eagerness and delight; and the need of a name for it clearly separating it from other kindred studies is every day more apparent.

It is my purpose to present in this paper a brief chapter in this science, following out and perhaps to some extent repeating some of the thoughts expressed in a paper presented to the Society two years ago,* in which I discussed the nature of the earliest human inventions, the original germs out of which they grew, and the steps and processes by which they were evolved or elaborated. Speculative as some of my suggestions may have been as to the nature of these primitive inventions, nevertheless the nature of the processes by which they were made is so inherent in all arts that it cannot be regarded as in any degree speculative. Possibly the inventions pointed out were not actually the first contrived by man, but whatever were the first, the way described is beyond doubt the way in which they were arrived at.

I propose in the course of this paper to discuss the development of the stone hatchet in its most finished form; but before doing so it is necessary to inquire into the nature of invention and some of the general principles it follows. Lying absolutely at the bottom of such principles are the following postulates, the A B C of Eurematics: Given any artificial implement or product, we must assume—1st, *that there was a time when it did not exist*; 2d, *that before it existed there must have been a creature capable of producing it*; and 3d, *that such creature before producing it must have been conscious of needing it, or must have had use for it*.

There can be no orderly discussion of the genesis of any art without recognizing the truth of these postulates at every step. Questions may arise upon resultant or collateral propositions, but, admitting all that can possibly be claimed for accident as an element in invention, these propositions are not to be questioned. They are fundamental, and no logical consequences that flow from them can be evaded.

The first proposition, that before any artificial product existed

* An Inquiry into the Origin of Invention. Vol. II, Trans. Anthropol. Soc., Washington. 1883.

there was a time when it did not exist, is not startling, and may be passed over for the second: before it existed there was a creature capable of producing it. This is as much as saying that no product of art came into existence simultaneously with its producer, and seems to be no more startling a proposition than the first; and yet, if I rightly interpret the ideas of most writers, they have failed to grasp even so common-place a truth.

The third proposition, that the producer must have been conscious of needing the product, or must have had use for it before producing it, is not at first sight so obvious. In fact I believe the failure to grasp this truth is a great source of error and misconception among many writers. No one, however, who has given any thought to the nature of invention, has failed to observe that every step in the mechanic arts has grown out of a pre-existing want. Not necessarily out of a pressing need. Invention now-a-days does not wait for the call to be so urgent that waiting can be no longer. Long before this stage necessities are anticipated, and the means by which they are overcome often do not become indispensable till the very habits they engender make them so. Illustrations of this are all around us. The sewing machine, the reaper, the telephone—what could we do without them? And yet in our own generation we have done without them all. They have themselves created the conditions which have made them indispensable. But none of them came by accident. They have been, every one, the fruit of years of toil and thought and anxiety on the part of those who saw, what few clearly comprehended, the imperfection of the means employed to do the daily work of mankind, and studied to produce better means. This is the history of steam, of electricity, of railroads, of metal working, of pottery, of every art that has a recorded history. Prevision and calculation are so truly elements in the growth of all known arts that in asserting their universality we incur no more risk than did Newton in asserting the law of gravitation.

What then, it may be asked, is the place due to accident in invention? Notwithstanding a popular belief that many if not most of the great inventions have been the fruit of accident, it may be asserted that the contrary is true. Fortuitous circumstances, trifling unforeseen incidents, have in many cases doubtless suggested expedients which have led to the consummation of great inventions. It was an accident—the result of his poverty—which led Senefelder to write on a stone slab his family wash-bill, and so led to the inven-

tion of the lithographic process; but the accident did not occur, and could not, till long and persevering pursuit of a method of printing cheap music had brought together the polished stone, the ink, the acid,—all the materials necessary to accomplish the result. Possibly it was an accident which led Goodyear to the use of sulphur for the vulcanization of India rubber; but the accident, if such it were, did not occur till years of expense and toil and experiment with a great variety of materials had led the way to it. And the rubber and the sulphur and all the appliances necessary for the experiment were ready to his hand, all accumulated in the pursuit of his lifelong purpose. Such experiences are common, and familiar illustrations of them are found, as for instance, in the lives of Palissy, the Huguenot potter, and William Lee, the inventor of the stocking loom. In these the element of accident enters in some degree into the consummation of the invention; but in every case it is such accident as might have occurred a thousand times over without result to other men whose minds were not intent upon the invention. Lamps had swung for centuries in the Italian cathedrals, and men had idly counted their oscillations as they kept time to the tedious delivery of generations of dull sermons; but the isochronism of their swing, if observed at all, was not regarded till Galileo came.

The true and only field that philosophy can concede to accident in invention is that it supplements and sometimes abridges the labor, calculation, and time of the inventor. To a man filled with a steadfast purpose, all his senses alert to every means chance or calculation may present to accomplish it, the most trifling incident may furnish the clue, which has fled from him like an *ignis fatuus*. To another the same chances may come and go continually without result. And while it cannot be said that accident has no place in invention, it must be conceded that its place is completely subordinate to other elements. Great inventions have been the fruit of accident in the same sense and to the same degree that a ripened peach is the fruit of the rude blast that shakes it from the bough.

It is important in a discussion like this to keep clearly in mind the difference between invention proper and discovery. The function of the latter is to bring to light the material facts, and the natural laws, which the former applies to useful purposes; and in respect to discovery, the element of chance, of accident, is im-

portant. The progress of scientific discovery is marked at every milestone by the revelations of accidents, which the thoughtful mind of the inventor did not apply to practical ends till long afterwards, when the need had arisen. If it was an accident that led Galileo to the discovery of the isochronous oscillation of the pendulum, it was not till fifty years afterwards that this discovery was applied to regulate the movement of a clock. The phenomena of electricity that accident may have revealed to Galvani and Volta, are the basis of inventions that the most active minds of this decade are expending their best energies upon. It cannot be denied that in discovery accident has played an important part; but the more this fact is considered, and the more we consider the true function of discovery, the more strongly do we find the proposition confirmed that improvements in the arts are not the result of chance but of intelligent efforts to supply conscious needs. Hence I shall regard this proposition as conceded, and I pass to another.

(4) *Every human invention has sprung from some prior invention or from some prior known expedient.* Inventions do not, like their protectress, Pallas Athéne, spring forth full grown from the heads of their authors. This suggestion needs no argument when made regarding any of the modern inventions. Every one of them is seen by the most superficial observer to be built upon or elaborated out of inventions and expedients previously in use. It is only when we go back of these and study the expedients and appliances out of which they have grown, and whose history is unrecorded, that the proposition I contend for is not obvious. And yet there is not a single one of them which does not when studied exhibit in itself the evidences of a similar substructure. In the process of elimination we go back and back, and find no resting place till we reach the rude set of expedients, the original endowment of men and brutes alike. This is a truth which study more and more confirms, and from it the proposition stated may be deduced as one of the laws of invention.

It may be deduced as a corollary to this proposition, but at the same time a fact determinable by independent observation, that the generation of one invention from another is not immediate but always through one or more intermediate steps. The effect of every invention fundamental in its character is first to generate wants before unknown or unfelt. The effort to supply these wants leads to

new inventions.* These may be quite distinct in their character from the original invention to which they indirectly owe their origin. They are related to it only as means to supply some want to which it has given birth. I shall not pursue this branch of the subject. Illustrations will occur to all. There is hardly a branch of industry that has not felt the effect of inventions based upon wants created by the introduction of petroleum, or the general use of the telephone. Wood-working, mining, transportation by land and sea—all the avocations of men—have felt their influence, have found wants engendered by their use, and improvements have been made to meet these wants. The wants of primitive man were limited, and his inventions were accordingly few. As wants increased in number and intensity, inventions multiplied, and the numberless wants of modern civilized life are only paralleled by its numberless arts and expedients.

I set it down as a fifth proposition: *Inventions always generate wants, and these wants generate other inventions.*

A sixth proposition is that the *invention of tools and implements proceeds by specialization*. This is true to a certain extent of all arts, though perhaps not a universal truth regarding all invention. It results, as will be apparent on reflection, from the last proposition. A single tool may have a great variety of uses, but, if there is a sufficient requirement, men will not long be contented with one tool for those uses for which it is least convenient. It will be reserved for that to which it is best adapted, and other forms will be devised better suited for special uses; possibly the parent type may be found inferior for all uses to some of its modified forms, and it may, on the principle of the survival of the fittest, become obsolete. Look at the variety of tools on a joiner's bench, chisels, planes, saws, each especially adapted for its particular work, but all pointing back to a time when there was but one form of chisel, or plane, or saw. The "jack-plane" and "long-jointer" may each be made to perform the work of the other, but they do it very imperfectly. The primitive bench plane was like neither, but was the type of

* A curious instance of this is brought to my attention while writing this paper. In consequence of the expiration of the earlier patents on roller-skates, a great impetus has been given to their manufacture, the result being the exhaustion of the world's stock of boxwood of certain sizes used for rollers. And to supply the want so created hundreds of people are trying to invent a suitable and cheap substitute for boxwood for this purpose.

both. There is nothing more striking than the variety of cutlery on a well-furnished table. The time is not remote when one knife worn at the belt served the purpose of all these, so far as these purposes existed, and of many others; when the table knife was not differentiated from the dagger of the soldier or the tool of the artisan. A man then used one knife to cut out a leather sole, to shape his arrow, to carve his food, and to stab his enemy. Changes in modes of living have led first to the broader specializations; fashion, caprice, and increasing refinement to others; till one scarcely dares attempt to enumerate the various forms of carvers and table knives of various sorts differing in form and material, each adapted by some feature for its particular use, and each the result of some degree of invention, with which the tables of Europe and America are furnished. Undoubtedly this process has gone on ever since man became an inventor, and might be illustrated as perfectly, though not so profusely, in the implements and weapons of the savage as in those of civilized men. All study of invention must take account of it. As soon as men began to adapt sticks to their use by artificially pointing them they began to find in them various degrees of hardness, weight, length, and rigidity, qualities fitting them for diverse uses, and as skill and experience were acquired they fashioned them accordingly. Likewise when man had begun to employ flint flakes, and before he had learned to fashion them to his will, he selected from the splinters made by accident or by his own unskilled blows those which served best such diversified uses as he had found out.

My seventh proposition, and final one so far as this paper is concerned, is that *no art makes progress alone*. I venture to assert the universality of this truth from what is seen in the recorded history of all inventions. In the development of the mechanic arts, two or more arts distinct in their nature but having close interdependence make advance *pari passu*. If one lags the other is necessarily retarded. If one makes rapid progress the other springs forward with quickened impulses. An improved utensil or article of manufacture may be the result of or may lead to improved processes and tools and machines for producing it, or to improved means for its employment. The progress of the steam-engine was long retarded by the imperfection of iron-working machines, since perfect cylinders could not be produced. The progress of electrical invention has necessitated the invention of new machines and processes for insulating

wire. The introduction of illuminating gas has created a demand for metal tubing, and machines for its rapid and perfect manufacture. And so every step in every art is marked by one or more corresponding steps in other arts.

These general principles, imperfectly stated as they are, by no means exhaust the study of invention. They only lie at its threshold. They are among the more obvious laws which inventions follow as they are every day presented to the mind of those who deal with them: so obvious, that I have found myself hesitating as to the value of their presentation in this form; a hesitation which is removed by observing that, so far as writers upon early inventions are concerned, they are unnoticed and apparently unknown. Further chapters in Eurenatics might be devoted to the elucidation of other truths equally generic and universal, but more intricate and therefore less obvious. I might cite for instance the tendency of civilization to convert luxuries into necessities, true not only of absolute civilization but of every stage of it or every step towards it. The effect of this tendency upon inventions is marked and positive. I might cite the fact that invention is stimulated by rewards and retarded by opposition, which history abundantly illustrates,—eminently the histories of France in the middle ages, of The Netherlands, of Great Britain, and of our own country. Another proposition might be that the truth regarding biologic evolution—that the type of any species which is to predominate is at its first appearance unobscured—applies equally to the evolution of arts. Many such propositions more or less recondite might be stated, the adequate discussion of which would require a volume; but I can afford to pass them by, as I have not set out upon an exhaustive study. The few propositions considered are enough for the present purpose.

I shall now discuss the progress of invention in a single direction, partly as a study in itself, partly by way of illustration of the doctrines I have enunciated. I have selected the stone hatchet for this purpose because in some of its ruder forms it represents the earliest human workmanship of which any knowledge has come to us, and also because in its rudest form it presents the evidences of being the fruit of long antecedent growth. Further than this I observe that primitive as it indeed is, and in its highest development rude and ineffective in comparison with the finished implement of this age of steel, the thoughtful student of invention sees in it the culmination for the time being of human art rather than

the beginning. For the purposes of this paper I regard nothing less than the hafted celt as the finished implement whose genesis I shall attempt to indicate.

I assume as the starting point the conclusion reached in my paper before referred to,* that the earliest mechanical process employed by man was the art of working wood by abrasion. This cannot be regarded as proven; absolutely proven it can never be; but it comes in as a link connecting what must have been in the history of primitive man with what is revealed to us regarding the man of the earliest stone age. This art, or something closely similar to it, appears as the immediate derivative of the original mechanical expedients of man in a state of nature, and of the wants engendered by his human characteristics. Tracing back the art of wood working we find no resting place till we come to the art in this condition. In short the more the subject is contemplated, and from whatever point of view, the stronger appear the probabilities, so strong that to my own mind they are convincing. Starting from this basis, what was the process, what the result sought, what the methods employed to produce it?

The object sought for was a pike, a strong, rigid, sharp-pointed stick or shaft adapted for use as an offensive and defensive weapon, a want early felt and hitherto imperfectly supplied by chance and nature. The means employed was a rough rock, a coarse sandstone or mill-stone-grit upon whose exposed surface the wood was rubbed or drawn back and forth until reduced as desired. A tedious process, but not more so than many of those employed to this day in the arts of savage life. We can imagine men coming from great distances to the inventor of this art with poles on their shoulders to be prepared in the new style. It would not at once be perceived that no special properties attached to this particular rock, that rocks having similar properties and perhaps better suited to the purpose were every where. The mind was dull in grasping the essential fact of the art, and perhaps for ages superstition and fetishism may have been engendered by this very improvement. It is easy to see, however, that it had created a new want, or perhaps intensified the old one. Pikes were liable to be broken, were subject to natural decay. They must be replaced, and new ones were always in demand. Their artificial production had increased the number of their

* An Inquiry into the Origin of Invention. Vol. II. Trans. Anthropol. Soc. Washington. 1883.

possessors, and the want of a ready means for the replacement was more widely felt. To the majority it was a new want. Hence among people widely scattered, more convenient and accessible means were sought for supplying the demand ; and in answer to this want came the discovery, perhaps the result of similar experiences and observations, that gritty rocks every where would yield the same results to similar manipulation by the hands of any one. And a further discovery followed close on the heels of this, that the jagged edges of flints and other hard rocks would by a manipulation but little varied perform the work better and faster than the gritty surface of the sand stones. A stick drawn forcibly over such a sharp edge has its surface scraped from it in thin shavings instead of being merely abraded as heretofore. This important step from abrasion to scraping, which is in fact cutting, was therefore reached before any cutting or abrading tool had been devised. Reached by slow steps, in answer to a felt want, but a want in no way pointing to it, it was actually the invention of another and quite distinct mechanical process. It was a better process, gave better results, and the weapon and the art of wood working made progress together.

We have advanced one step, man now has the notion of the cutting edge and its use. But it is part of an immovable boulder or ledge, not always accessible, and the want of a convenient means always at hand is but partially supplied. The long pilgrimages which had to be taken to the primitive pointer of pikes were at an end, but the journeys though shorter still have to be made. How was the next step, resulting in the production of a portable cutting implement, to be accomplished ?

It will be seen at once that in the use for a considerable period of the edge of a rock for cutting purposes it will become dulled. Other parts of the rock having exposed edges will be sought, and these will become dull in turn. This dulling process proceeds more or less rapidly according to the material applied to it ; and as the harder woods were found to be in all respects more serviceable they were more generally used. We may conceive that at some time by the violent application of a hard piece of timber to an edge somewhat thinner than ordinary, the edge itself instead of being merely dulled is broken off, and to the pleasant surprise of the operator a new edge, sharp and clear, and better than the half-dulled one he had been using, makes its appearance. And he eventually learns that he can at any time produce a new edge by shivering off a piece

of the rock with blows. He is not long in learning that the part broken off has similar edges. If it be large enough to lie firmly he can employ it as he does the parent rock. If smaller, he may hold it firmly with his feet while he manipulates the wood upon it with his hands. Perhaps he can carry it away and use it at the place most convenient to him; when dulled he can shiver it by a blow or two and it is sharp again. And then at last by slow degrees, requiring ages perhaps, one can hardly tell how, but by the continuance of this process, he observes that these splinters struck from the fragment, these fragments of fragments, possess the same cutting edges as the original rock, and in a bit of stone not larger than his hand or his finger he possesses an instrumentality capable of doing all that he and his ancestors have been laboriously doing on the parent rock or clumsy fragment. He learns also that instead of dragging the wood over the edge, he can, with a totally different manipulation, hold the wood firmly and operate on it with the stone splinter, and the tool is invented.*

When I think of man in his primitive condition, as the logical necessities of this subject have compelled me to think of him, helpless, miserable, the prey of beasts, without tools, without means of defense except such as he shared with the beasts, and then think of him in the condition to which he is brought in this outline of his inventions, I find it impossible to adequately express my sense of the progress he has made. One effective weapon, its structure improved, and skill in its use acquired by generations of experience, and one cutting tool, even in the rudimentary form of an unfashioned flake, have separated him incalculably from the condition of his ancestors. His knife or hatchet, as we may henceforth call it, contained within it all the possibilities of the future, but for the present—his present—its capabilities were learned by constant lessons and with every new occasion. He had no want to which it did not minister. It not only served its first purpose to prepare his weapon, but it became itself a weapon. It served him to procure and prepare his food, both animal and vegetable, his shelter, his raiment, if he had reached the stage of wanting raiment. Its

* It is only by a loose construction of language that this can be called the invention of a tool. The tool, a mere flake of stone, had already long existed. . The actual invention was an art or process quite distinct from any heretofore employed. The brief and more popular form of expression may be employed with this explanation.

acquisition was the greatest step he had taken in invention; and when we regard what has grown out of it, the infinite variety of cutting tools, implements, and machines, whose origin we remotely trace to it, and the unnumbered needs they supply, we cannot hesitate to ascribe to it the highest place among all the inventions of all time.

If the hafted celt was for the time the culmination of art, this is not less true, of its time, of the flint knife. As in man's rudest estate he used the expedients with which nature endowed him, selecting those best adapted to his immediate purpose, so now out of the diverse forms assumed by flakes and chips, he selects those best adapted for particular purposes. He is repeating what occurred in his earliest period, but with new and diversified wants, wider intelligence, and a greater range of material out of which to select. He finds blunt edges give satisfactory results in the old process of scraping wood, but he finds that thinner and sharper edges penetrate the wood deeper, and remove the superfluous material faster. He finds he can work more deftly, more conveniently, can put a finer point on his weapon, can apply the new tool to all parts of it, can reduce and trim the shaft as well as the point, can even sever the growing saplings to obtain his material. He finds that some forms can be made to penetrate and divide the tough skins of beasts, and carve their flesh. In fact, in whatever direction his necessities or inclinations lead him, he finds his knife in some form contributing to his comfort, his protection, and the supply of his wants. The possession of the tool has wrought out his mastery over nature.

This culmination in invention is but momentary. It is a milestone, a breathing place in the history of arts. But the march still goes on, and we find man still searching among fragments for forms adapted to his particular uses, but gradually learning by experience that by well-directed blows he can sometimes produce chips having special forms, and so fitted for special uses. But these are chips and flakes only. There is no attempt as yet at dressing or shaping stone. The rude forms they bear when shivered from the rock, are all that man has yet conceived in the structure of a stone implement. These rude forms seldom appear in our museums. They are the scoff of archæologists. They are not distinguishable from the work of the elements. In fact, the splinters thrown off by frost or fire may have been as readily selected for use as those formed by human agency. And as writers have agreed upon

the name *palæolithic* to indicate the age marked by the first traces of human workmanship in stone implements, we must recognize the *protolithic* age, in which stone fragments showing no trace of such workmanship were the common implements of mankind. The earliest age of wrought implements could never have come but for such a precursor. The rudest wrought forms did not appear till something of the same nature and used for the same purposes, but imperfectly adapted for their performance, had created the need of them and led up to the means for its supply, and the one thing which bore these relations to the earliest recognizable forms of dressed-stone implements was the unformed flake.

What were the steps from this form of flint knife, or scraper, or hatchet, to the hafted celt?

I formerly reached the conclusion that the original endowment of man could include no less than the stick and stone for striking and hurling, and the string or withe for tying or binding. In the course of this paper I have traced the synchronous development of the art of dressing wood, and of stone appliances for the purpose. With the advancement of these it is not to be supposed any former art or expedient was lost. On the contrary it is to be presumed that progress in them had been made corresponding to that we have been following. The club was better fashioned; approved forms of hurling-sticks may have been discovered and come into use. Greater skill may have been acquired in the use of the hammer-stone, and judgment in the selection of suitable forms either for crushing, or for splitting, and with more convenient hand-grasp. The flexible vines and strips of bark, with which primitive man lashed his frail shelter, his successor may have improved by rudely twisting the fibres or strands, or have supplemented by other materials, notably, after he had acquired the use of the flint knife, by strips of skin and animal tendons. The inventory of his possessions then would embrace the club and pike, each clearly specialized, the hammer-stone, not formed by art but selected, the stone knife, and strings of various materials. The pike, the hammer stone and knife may have been of many forms. Now it will be seen that these elements may be brought together in various ways so as to accomplish a variety of results, the elements in every case being a stick, a stone, and a string to bind them together, and the difference in result depending on the particular form of stick and stone. For instance the heavy end of a club is made heavier by lashing to it a hammer stone—result the mace. The pike is improved by securing to it a

pointed flake of flint. A flint flake too small for the hand is made effective by fixing it to a piece of wood, making a knife or dagger. A heavier sharp-edged fragment secured to a handle adapting it for striking, becomes the axe or hatchet. What immediate incidents or needs led to any of these combinations, I do not propose to guess. It is enough to have shown that at a period when man was as yet unlearned in respect to any dressing of stone beyond knocking off rude splinters from a rock, he may have had in his possession the means to produce, and was fully capable of producing, such implements and weapons as I have named. This being true, the same wants which might at any period of his history have led to their production may without violence be presumed to have done so then. They are in the line of his acquired arts, and the necessary links between these and the arts he is yet to acquire.

Whether these various combinations were made prior to actual working of flint it would be idle to speculate. It is more likely that neither preceded the other. While man was finding out how to use his possessions by bringing them together in new combinations, he was naturally improving them all. Having found the flint and other rocks of similar texture so far obedient to his power that they could be shattered, and new and useful forms produced, having acquired uses for these forms, having learned the purposes to which a sharp edge could be applied, and that a fresh one could be produced by knocking off the dulled one—it followed in due course, from experience, to form the new edge with less violent blows, with more judgment and dexterity, and, as the advantage of special forms became apparent, with a view to bringing it as close as possible to such forms. And all this time the old art of reducing by abrasion had not been lost; applying it now to the stone as finer and finer chipping suggested and provoked the desire for a smoother edge, the celt appeared, polished at first on its edge only, afterwards on its entire surface. There was no dividing line between the palæolithic and neolithic ages. If separated at all, it is by a broad zone through which the implements of both are found side by side. Neither was there any step from the finished celt to the hafted implement. The essential step, that of securing a stone in some form to a handle, had been taken long ago.

Lest it might be suggested that in order to sustain a theory regarding the development of the arts, I have myself been led to invent steps in art that were never known to man, it is worth while to remark

that none of the steps I have set forth are imaginary. All of them are in existence and in use yet, in their appropriate places, often amidst the completest appliances of modern mechanic arts. If the primitive man sharpened a stick by rubbing it over a rough grit, he used the same means an artist employs to-day to produce a fine point on his pencil, and the same by which we sharpen all cutting tools. The scraping tool is one of the ordinary provisions of a joiner's outfit; but the use of a bit of broken glass is more common still. As the edge becomes dulled by use, the glass is simply broken and two fresh edges are formed. This is universal in civilized life, and a curious instance of it in savage life has just been brought to light by the Rev. Lorimer Fison, in his pamphlet on the Nanga or Sacred Stone Inclosure of Fiji, in which he relates often having seen "a mother shaving her child's head with a bit of glass, and biting a new edge on the instrument when it became dull." These original arts have never been lost. Probably it is a general truth regarding mechanic arts that no one of them once commonly acquired is ever again lost. It may be laid aside for a time or suspended, but it revives in some form; and I venture to think that much of the eloquence that has been expended upon the "The Lost Arts" has resulted from a very imperfect acquaintance with those that exist.

It is apparent that every step in the progress that has been recited resulted in an improvement in man's condition. The first improved weapon, club or pike or missile, was equivalent to so much greater strength of arm or length of reach. It augmented man's superiority over the brutes; it made his life less precarious; it put the means of securing food, shelter, and covering more fully within his power. His environment, to which he had in his primitive condition been completely subject, he now could to a certain extent control, could subject to himself. The first improved means of fabricating a weapon, the first tool or mechanical process, accomplished these results in an increased ratio. The step that made the cutting tool the possible possession of every man, which made the knife even in its clumsiest form a common tool, did for the whole race what the earliest steps did for a limited number, and made this amelioration general. The increased number of forms and varieties of tools and weapons, growing out of the diverse and manifold wants they were adapted to supply, were each steps in the betterment of his material condition, each an indication of progress; man's advance towards civilization, slow as it must have been, was

marked off step by step by the advances he made in his mechanic arts. The more he became independent of nature and capable of forcing her into his service the more time and inclination he found for the perfecting of his implements; and the more he perfected his implements the more capable he became of subduing nature. And this interaction has never ceased, it goes on to-day. But the achievements of to-day are not the conquest of savage beasts, nor the solution of the problems of food and shelter and warmth. We are overcoming time and distance; we are conquering the barriers of sea and mountain; we are finding out the more hidden forces of nature, and subjecting them. The fruit of our inventions is not seen in rough flakes of stone lashed by sinew to rude hafts, but in the mighty movement of the railway train thundering across the continent, or the click of the telegraph as London talks with Calcutta. And every step in progress has been a step in the improvement of man's condition from the first to the last. And so it shall be in the future.

Artists depict the genius of invention as a voluptuous female figure, in various stages of imperfect attire, attended by innocent boys in their primitive nudity, and with gear wheels and anvils and other rough equipments of the artisan in ill-assorted proximity. This is a feeble conception. The genius of invention is not a creature of delicate mould, but one of brawn and sinew. His voice is no gentle song of lullaby, but comes to us in the deafening clatter of Lowell looms and the roar of Pittsburgh forges. Mighty and beneficent and responsive to human wants—this is the kind of song he sings in his rugged rhythm:

“I am monarch of all the forges:
 I have solved the riddle of fire;
 The amen of Nature to cry of man
 Answers at my desire.
 I grasp with the subtle soul of flame
 The heart of the rocky earth;
 And hot from my anvils the prophecies
 Of the miracle years leap forth.

I am swart with the soot of my furnace,
 I drip with the sweat of toil;
 My fingers throttle the savage waste,
 I tear the curse from the soil;
 I fling the bridges across the gulfs
 That hold us from the To-Be;
 And build the roads for the bannered march
 Of crowned humanity.”

DISCUSSION.

Mr. P. B. PIERCE, discussing the paper, referred to some of the curiosities or phenomena of invention; for this science of *eurematics*, like every science, has its attendant phenomena. Indeed, that invention is a science is demonstrated by its attendant phenomena.

Invention is not creation; the first deals with matter direct; the latter supplies that with which invention deals. The student of *eurematics*, giving heed to what the history of his science has to teach, soon discovers the principles of the great law of evolution. Let him inspect the almost humanized giant that bears its load of living freight daily from Washington to New York in less than six hours, and what does he find, except that since the days of Watt the process of selection or differentiation has been intelligently going on! The clumsy, the crude, the ruder elements have been rejected; the harmonious, the simple, the efficient, and stronger have been utilized. Increment by increment complexity has given way to simplicity, until the perfected machine stands forth as we know it; that is to say, the machine we are pleased to call *perfect*, the selected excellence, the *summum bonum*, of all that experience and long use have taught to be best of those that have preceded it. Each inventor has contributed his mite, and lo! the grand result! And its maker, man, is he not perfecting himself along with that dull matter upon which he works and in which he achieves! Is he not, as described by the poet,

The heir of all the ages in the foremost files of time?

Is not matter reflex? Is Frankenstein in reality the monster his author portrayed him to be? Will not the science of *eurematics*, when once fairly beset by the persistent inquisition of scientific study and investigation, open wide the door of the temple that is even now ajar, and permit its disciples to enter and make intelligent conquest, under a full knowledge of its laws, where until now they have only been permitted to make occasional, random captures from the *vestibulum*, as it were?

The thousand forces of nature lie hidden within grasping distance; but for lack of systematic study they elude our clutch, escaping from our wildest approaches as the thistle down upon a puff of air. This may not always remain so. The Lilliputians bound Gulliver with straws; let us ply Nature with pitiless interrogation till she yields

us the fullest knowledge of all her laws. For this is eurematics in its broadest significance; it is encompassing the laws of nature with material form and compelling matter to do the bidding of psychical energy.

But evolution does not account for all. There is in invention a synchronism that is almost mysterious. The present is the grand harvest time of all the seed that has been planted by the generations that have preceded us; but why the thoughts of inventive minds appear to move in battallions, all aiming at some common objective, seems at first view almost inexplicable. A given function is demonstrably demanded; a hundred minds set themselves at once, in all parts of the world, to produce the means for its satisfaction. With the almost universal diffusion of information that has come about with the art of printing, even in all languages and tongues, aided by the telegraph and the telephone, who fails to know in all the broad earth to-morrow morning what the chiefest want of to-day has been? Within one month's time from the great flour-dust explosion in the mills of Minneapolis, in May, 1878, there were over thirty inventions made for preventing the recurrence of such an accident, and all practically effective. Many of them were almost if not quite identical, although made by men having no knowledge even of each others' existence, and in all parts of the world! So quickly, when a pressing want is known, is the means supplied for staying the same. When the science of invention has been perfected, and every want has been given a means for its satisfaction, will not the highest type of invention then be the discovery of a new want, latent in the human soul, but never before developed?

Another feature of invention noticeable to an attentive observer is the isolation in which an important discovery is often times set. The evolution of the automatic grain binder of this day, from the sickle of Egypt and the Orient, is plain and familiar. To one who has witnessed the devouring knives of this latest type of human genius, hungrily levelling the yellow harvests of the great northwest and tossing the bundled sheaves backward in serried rows upon the stubble, and contrasts its action with that of the reaper in the time of Boaz, how far apart they seem separated! And so they are, wide centuries apart. But the quick mind of invention anticipated the want almost in the earliest day of the reaper. In the year 1854 two men invented, perfected, reduced to practice, and patented the

completed machine whose opportunity for use did not come until twenty-five years later. Like lonely islands arising out of the receding waters of an ocean, such inventions, though they may afterwards be the highest lands of great and fundamental enterprise, are lost for want of use. Although pioneers their inventors are without remuneration because they are too far in front of the needs of the world. The world itself is ever unready; the lines of necessity are conservative and strenuously refuse to make room for the new applicant for favor, even though full of promise.

Mr. WM. H. BABCOCK said no one, on glancing over our patents, can fail to observe how many of the inventions covered by them are obviously outgrowths of those already in existence rather than contrivances adapted to meet any real want. A man sees a particular machine, or a description of one, and forthwith proceeds to devise a similar but slightly different construction. Thus there are, for example, more than three thousand patents on car couplers, most of them varying from others in a trivial degree, very few of them being actually in use. A large class of our inventions are of this incidental kind.

But another large class of inventions have grown mainly out of a distinct conception of a public demand, real, foreseen, or fancied, or of the practical needs of manufacture. Exclusive of certain sporadic and eccentric instances, inventors are either manufacturers, the men employed by them, or who expect to sell to them. All these are on the alert to note the drift of public taste and practical requirements. A manufacturer sees, or thinks he sees, that a new article, or a change in an old one, would meet with or lead to a considerable sale; or that a simplification of his machinery would enable him to reduce his force or his fuel; a factory hand finds that the machine with which he works has some persistent, annoying defect which a slight alteration would avoid; an outsider in a factory village forms his own theory as to what would give one competing manufacturer an advantage over another and knows that it would be well paid for; in all these influences the exertion of ingenuity is easily accounted for.

The effect of the public demand is curiously illustrated in the synchronism of invention. It frequently happens that men widely separated territorially and having no discoverable communication with one another make the same invention at the same time, or so nearly at the same time that priority cannot easily be determined.

The progress of a certain art has reached a point where a given step becomes inevitable, and like causes produce like results everywhere.

This shows, further, that the individual man is of less importance as a factor in invention, than his environment. Indeed invention in the wide vague popular sense can hardly be said to exist. Even our greatest inventions have proceeded by a succession of small increments. Each man puts a round in the ladder, and the next climbs on it to put in his higher up. The one who puts in the last round steps from it to receive the crown of success, although his contribution may have been the least of any; and his even more meritorious predecessors who failed, but made that success possible, are generally forgotten.

Invention for the pleasure of inventing is of prime importance in literature and art, and cannot be wholly ignored even in treating of mechanical matters. Many men delight in experimenting with machinery, combining element with element, adapting every part with every other and to the end in view. They find invention "its own exceeding great reward." Every one who deals with inventors can recall such enthusiasts, who are often men of notable if narrow ability, and, on the whole, the most interesting of their tribe.

Mr. A. W. HART said: I am very glad that, among other things he has done, Col. Seely has put his foot down on the theory that accident is the mother of invention. This is a popular error which most of us may have sometime shared—certainly, I must admit it was included once in my catalogue of sins. What are called accidents are in reality normal results of a search or inquiry, or series of experiments, such, for example, in the geographical field, as the discovery of America by Columbus, or in the healing art, the prevention of cholera by inoculation with cholera germs if that is the correct term. In the way of a homely illustration, I will relate a personal incident. A friend proposed a walk to Arlington, and said we would look on the way for Indian arrow-heads. I assented but said that I never found an arrow-head in my life. "That is merely because you never looked for them," replied my friend. We went, and sure enough, found the arrow-head, and I found another the next walk I took in search for one. Now, while in a certain sense I may call that finding an accident, in the true and proper sense, it was none at all. It was the regular legitimate result of the search instituted. But for the preparation or plan and its systematic execution, the "accident" of discovery would never

have occurred. So inventions come when we are ripe for them and look for and strive after them—and then they are not accidents, but logical endings of systematic beginnings—just as the solution of a mathematical problem follows its working.

One may walk—as the savage does—over diamond or coal fields, rich bottom lands, or gold-bearing rocks, seeing nothing of their nature, contents or potentialities because intent on other things—of the hunt or war—and because not developed to any possible comprehension of anything more. But the civilized and mentally and scientifically developed man, going over the same ground might make valuable discoveries, for good to himself and his fellows, while losing sight of the beasts or the signs of presence of others that the eye of the savage takes in. The latter is therefore not to be charged with negligence, nor the civilized man with being the victim of an accident. So inventions come when we are ready for and seek them, —as apples fall into the basket we hold to catch them when ripe and ready to drop.

Mr. MURDOCH read a paper on the “SINEW-BACKED BOW OF THE ESKIMO.”

All the branches of the widely-distributed Eskimo race now live in regions which are either treeless or else deprived of the ash and other elastic woods fit for making bows. The fact that the bow was in general use among the Eskimo previous to the introduction of firearms is one of the arguments that they have not always lived in the regions which they now inhabit, but have moved on from places where wood suitable for the purpose was to be obtained. As they gradually became settled in their new homes, probably before the different branches were so widely separated from the original stock as they are now, and as the simple bows which they had brought with them from their old country became worn out and had to be replaced, it was necessary to find some means of giving the needful elasticity to the brittle spruce and fir, frequently rendered still more brittle by a long drift on river and sea, followed by exposure to sun and rain on the sea-beach. In some places even driftwood is so scarce that bows were made of no better material than dry antler. The elastic sinews of several animals, especially of the reindeer, furnished the means desired of making an efficient weapon out of these poor materials. This is not employed in the way used by the Indians of the plains, who glue a broad strip of sinew along the

back of the bow, but is braided or twisted into a cord the size of stout whip-cord, which is laid on in a continuous piece so that there are numerous strands of the elastic cord running along the back of the bow so as to be stretched when the bow is drawn. The simplest or, so to speak, ancestral pattern of sinew-backed bow from which the types now in use are evidently derived is one in which there are a dozen or twenty of such plain strands along the back, running around the "nocks" and held down by knotting the end of the cord round the handle. Bows of this form, slightly modified by having the cords somewhat twisted from the middle, so as to increase their tension, are still to be found in Baffin Land, where many of the arts seem in a lower state of development than among the Greenlanders, on the one hand, or the Western Eskimos, on the other. Let us now consider how in course of time the different branches of the Eskimo race have improved upon this simple invention. Along the well-wooded shores of southern Alaska, from the island of Kadiak nearly to the mouth of the Yukon, where there is plenty of fresh, living spruce, they have chiefly increased the efficiency of the bow by lengthening and broadening it, and have paid but little attention to the sinew backing, contenting themselves with slightly increasing the number of strands, wrapping them round with a spiral seizing, which prevents them from spreading, and occasionally adding a few more strands which only extend part way to the tips, being secured by hitches round the bow. This makes the bow a little stiffer in the middle than at the ends, where less strength is required. On the other hand, the people who live along the treeless shores of the Arctic Ocean, from the Mackenzie river to Bering Strait, can obtain no wood better than the dead and weathered spruce which the sea casts upon the beach. Consequently, all improvements in the weapon were of necessity confined to the sinew backing, which has developed into a marvel of complication and perfection, while the bow itself is rather short and not especially stout. Starting as before with a loop at one end of the cord strands are laid on fromnock to nock until there are enough of them to give sufficient stiffness to the ends of the bow. Then the cord goes only to within 6 or 8 inches of the tip and is secured round the bow by hitches, sometimes a very complicated lashing of as many as a dozen half hitches alternately in opposite directions, and returns to a corresponding place at the other end, where it is similarly hitched. In this way strand after strand is laid on, each pair shorter

than the preceding, and the backing constantly thickening towards the middle of the bow. When sufficient strands are laid on they are separated into two parcels, and with a pair of very ingenious little bone or ivory levers are twisted from the middle into two tight cables, so that the twist of the cords adds to the resistance to be overcome in drawing the bow. These are prevented from untwisting by a lashing at the middle which runs through the cable and round the bow in a sort of figure of 8. The end of the cord then makes a tight spiral seizing round the bow which not only keeps the backing from slipping, but serves to distribute the strain evenly and keep the bow from breaking. This pattern is probably the ultimate development of the sinew-backed bow. Not only is it difficult to imagine making a more perfect weapon from the material, but attention will no longer be paid to possible improvements in a weapon which is rapidly falling into disuse. As would naturally be supposed the region about Norton Sound, where the tribes of the Arctic coast meet those of Bering Sea, is a debatable ground, where bows of the two types described are found side by side, along with others partaking of the characteristics of both. If now we cross to St. Lawrence Island, we find Eskimos depending solely on driftwood, who employ another and most peculiar modification of the original type. They have lengthened the ends of the bow so that the original simple backing hardly reaches within a foot of either end, while these ends are bent up as in the Tartar bow, and separate backings are stretched across these bends.

The Eskimos of the mainland of Siberia, who have long maintained direct intercourse with the St. Lawrence Islanders and with the Eskimos of the Arctic coast by way of the Diomedes, show the evidence of this intercourse in the pattern of their bows, using either the peculiar St. Lawrence type, or purely American bows of the Arctic pattern, or weapons which curiously combine characteristic features of both.

DISCUSSION.

Mr. BATES said that the little blocks which are tied into the concave outer limb of several of Mr. Murdoch's bows are something more than a mere stiffener of the wooden portion. It is a truly mechanical expedient, to give efficiency to the tension member of the combination, which is the sinew. It not only acts as a strut to increase the leverage of the tension member, which is the

function of the strut in all combination trusses, but it shortens and straightens the line of the sinew, thus bringing its rigidity and elasticity into full play. In this, as in so many other instances of merely experimental evolution, the best results of abstract theory are arrived at.

NINETY-SEVENTH REGULAR MEETING, May 19, 1885.

Vice-President Dr. ROBERT FLETCHER in the Chair.

The Chair announced the death of Count Giovanni Battiste Ercolani, of Bologna, Italy, a corresponding member, after which a memoir was read by Dr. E. R. Reynolds, who, in the course of his remarks, presented to the Society an embroidered Italian flag and a number of scarfs and mourning wreaths contributed by various scientific societies of Italy, of which Count Ercolani was a member. The Chair remarked that Count Ercolani would probably be remembered principally for his discovery that the circulation of the blood was known and promulgated prior to Harvey.

Dr. MATTHEWS then read a paper upon "THE CUBATURE OF THE SKULL," which was followed by some inquiries by Dr. Frank Baker and Mr. Bates, leading to further remarks by Dr. Matthews.

ABSTRACT.

The lecturer discussed briefly the various methods which have been employed in the volumetric measurement of the cranial contents and pointed out their various defects. He then described a method which he had recently devised and employed in the Army Medical Museum at Washington.

After recording the weight of the skull it is varnished inside with thin shellac varnish, applied by means of a reversible spray apparatus. Artificial or accidental orifices are closed with India-rubber adhesive plaster. The foramina and fossæ are filled with putty. The skull is wrapped in a coating of putty an inch or more in thickness, which renders it water-tight. It is filled with water by means of a special apparatus in forty-five seconds and emptied in fifteen seconds. The rapidity of this manipulation in conjunction with the varnishing prevents soaking into the sinuses and the undue measurement of water which does not pertain to the